

U.S. Bureau of Land Management Technical Report UT020-FY14-001
(1 November 2013 Revision of 12 July 2011 PowerPoint Presentation)

ABSTRACT

The ion mass balance, which occurs naturally in the solid and aqueous phases of the Bonneville Salt Flats salt crust and accompanying shallow-brine aquifer, was originally illustrated as series of qualitative conceptual schematics in a 12 July 2011 PowerPoint presentation. Ion mass balance refers to maintaining the ions comprising the shallow-brine aquifer total dissolved solids in a quasi steady-state concentration.

The objective of the presentation was to qualitatively 1) show the cyclic effects of seasonal weather events on the ion mass balance between solid and aqueous phases prior to human-made impacts, and 2) demonstrate potential for the Salt Laydown Project to help maintain this balance during commercial brine withdrawal from Bonneville Salt Flats for potash production.

INTRODUCTION

This PowerPoint presentation was prepared for Barry Newman, reporter for the Wall Street Journal, who was planning to write an article about the Bonneville Salt Flats (BSF) (White 2011). The objective of the PowerPoint presentation was to simply explain the concept of ion mass balance. Specifically, the resulting schematic presentation describes: 1) the natural chemical balance between the solid-phase salt crust and the aqueous-phase shallow-brine aquifer, which bathes BSF salt crust; 2) seasonal weather effects on this balance between solid and aqueous phases; and 3) potential for the Salt Laydown Project to help maintain this balance during commercial brine withdrawal from BSF for commercial potash production.

Based on Mr. Newman's 2011 interviews with the racing community, the potash mining company, and the Bureau of Land Management Salt Lake Field Office (BLM/SLFO), he published an article entitled "Racers at Bonneville pepper potash firm with complaints." See The Wall Street Journal, 28 July 2011; <http://online.wsj.com/article/SB10001424053111904800304576472240063944226.html?KEYWORDS=bonneville+salt#articleTabs%3Darticle>).

Originally, the Salt Laydown Project was a five-year cooperative experiment conducted by BLM/SLFO and a potash mining company from 1997 through 2002 (White 2002, 2004). Its objective was an attempt to replenish salt to the BSF salt crust. The project was continued voluntarily by the mining company from 2003 through 2012 (White 2012). BLM/SLFO recently completed an Environmental Assessment (EA #UT-020-2006-002, August 2012) of the potash company's proposed mine and reclamation plan and issued a Decision Record (DR September 2012). This decision requires that the company 1) continue the Salt Laydown Project for the life of the potash lease; 2) balance amount of sodium chloride withdrawn annually for potash production with an equal amount to be returned by Salt Laydown Project; and 3) perform through a third-party contractor a repeat of the BLM/SLFO 2003 salt-crust thickness study during 2018.

SCHEMATIC SUMMARY & DISCUSSION

The original PowerPoint presentation consisted of 15 figures with accompanying figure text, and is reproduced in the following section. **Figure 1** illustrates the regional setting of the BSF within the Great Salt Lake Desert and its position within the 975-square mile area of the shallow-brine aquifer. **Figure 2** is a salt-crust thickness contour map and accompanying cross-sectional view of BSF north of Interstate 80 (I-80).

Figures 3 – 15 are simplified and qualitative schematic representations of the central portion of the salt crust showing: 1) the natural ion mass balance between the solid-phase salt crust and the aqueous-phase shallow-brine aquifer prior to human-made impacts (**Figures 3 – 7**); 2) seasonal weather effects on this balance between solid and aqueous phases (**Figures 4 – 7**); and 3) potential for the Salt Laydown Project to help maintain this ion mass balance during commercial brine withdrawal from BSF north of I-80 for potash production (**Figures 8 – 15**).

Detailed step-wise descriptions and discussion are presented in the accompanying figure texts.

Regional and Local Setting of BSF (Figures 1 – 2)

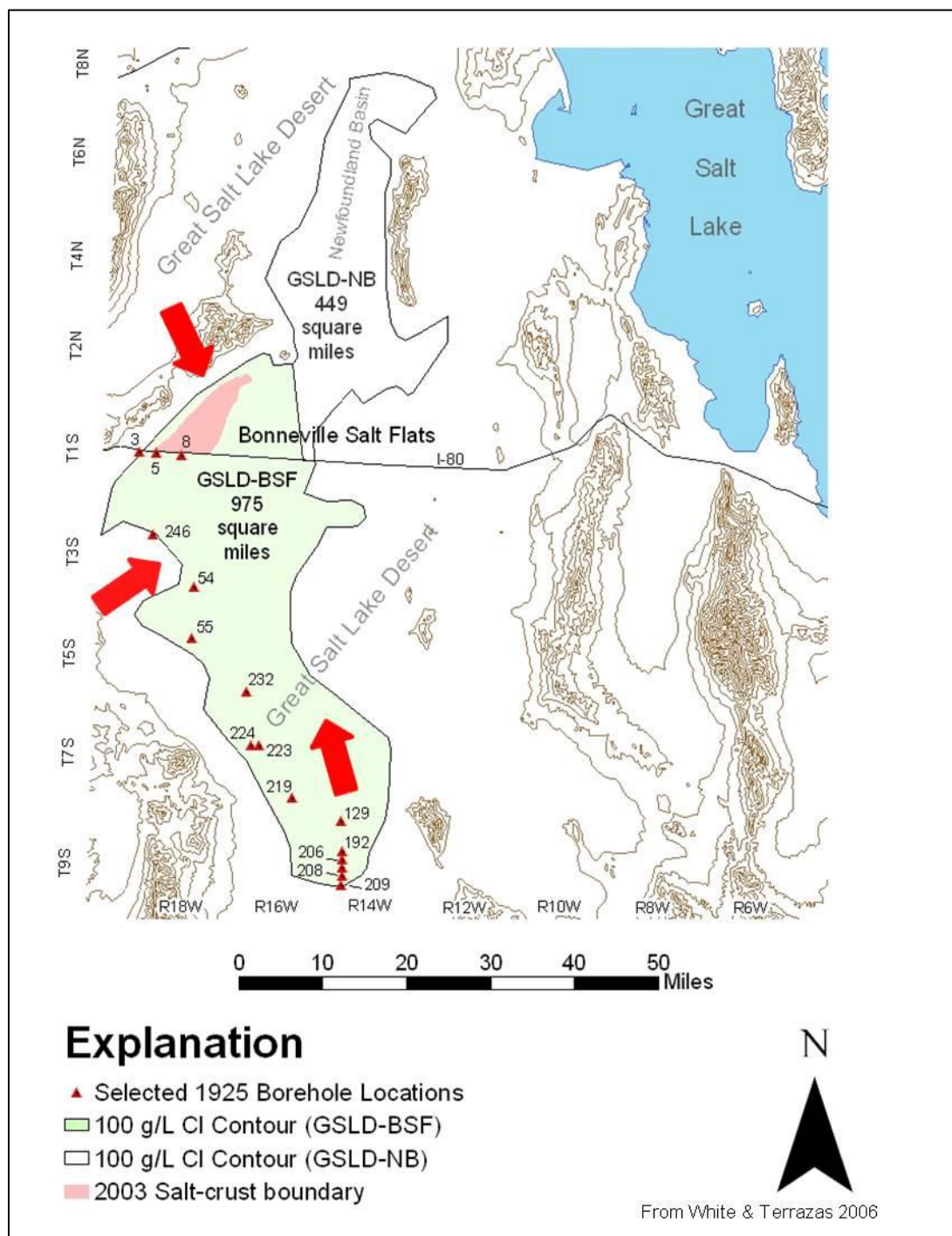


Figure 1. - Map of the Great Salt Lake Desert showing the Bonneville Salt Flats and its position within the 975 square-mile shallow-brine aquifer. The red arrows illustrate the general groundwater-flow direction of the shallow-brine aquifer, which discharges at the Bonneville Salt Flats (the lowest point in this portion of the Great Salt Lake Desert).

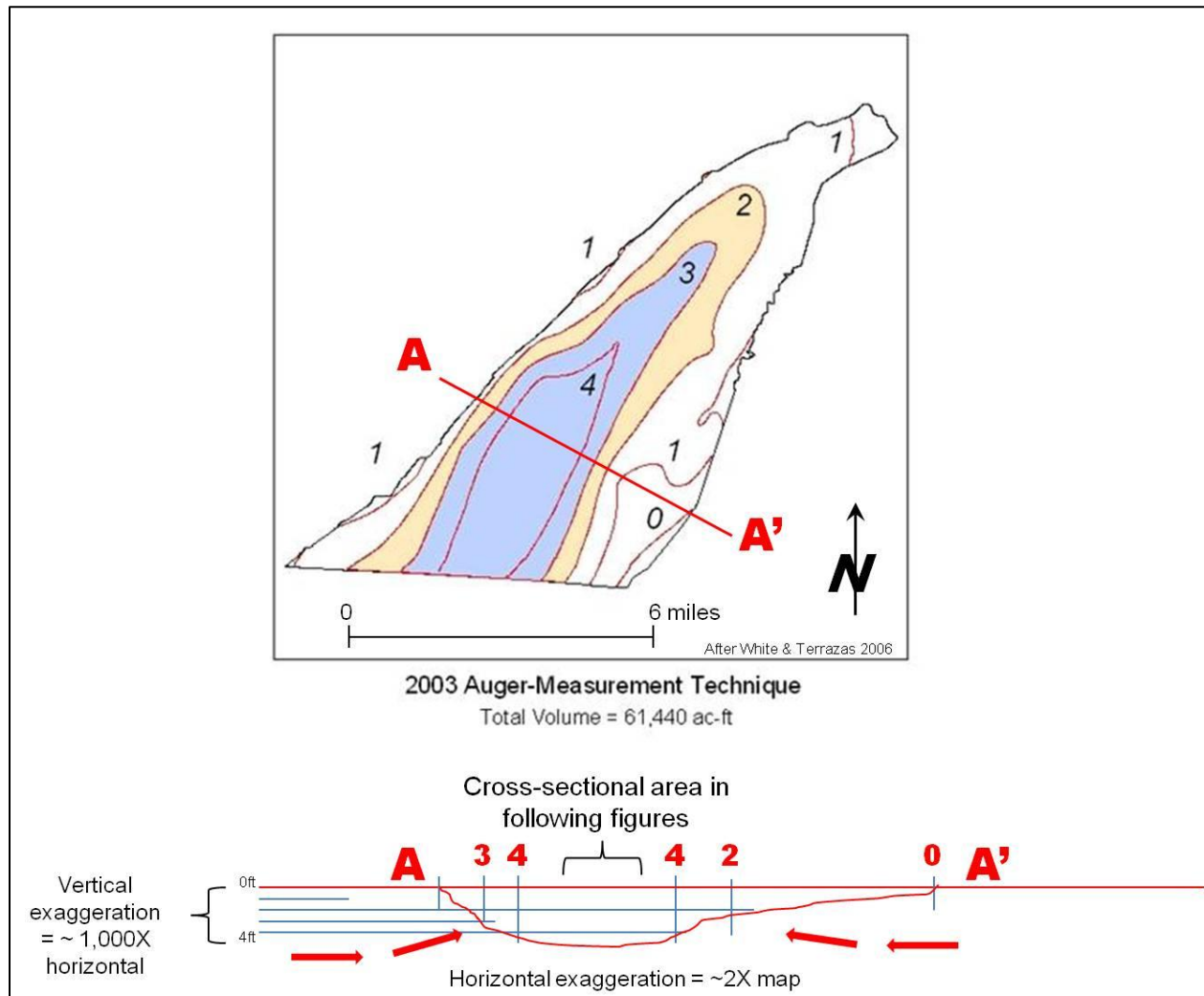


Figure 2. - Plan view of the Bonneville Salt Flats north of Interstate 80, showing the range of salt-crust thickness (0 through 4 feet) represented by thickness contour lines. The cross-sectional view of the salt crust (A – A') shows it to be an asymmetrical lens, which thins gradually toward the southeast. The red arrows illustrate the upward discharge direction of the shallow-brine aquifer. The red numbers represent the positions of the thickness contours where they intersect the cross-section line A – A'. The following figures (Figures 3 – 15) are simplified schematic representations of the central portion of the salt crust (represented by the bracketed area in the cross section).

Seasonal Weather Effects on Natural Ion-mass Balance Between Salt Crust and Shallow-brine Aquifer Prior to Human-made Impacts (Figures 3 – 7)

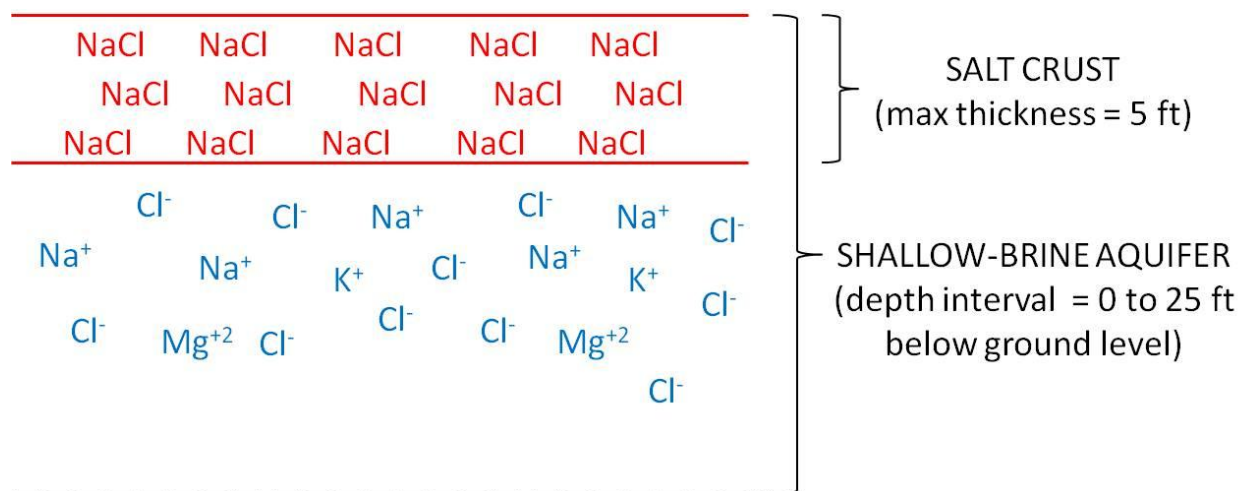


Figure 3. - Cross section of the salt crust and underlying old Lake Bonneville lake sediments (mainly clay strata).

The salt crust solid phase is made up of three halite strata (halite is the mineral name for crystalline sodium chloride and is designated here as NaCl). The shallow-brine aquifer's aqueous phase is a briny groundwater composed of positive and negative ions that resides in the porous portions of the old Lake Bonneville sediments and also bathes the salt crust. The positive and negative ions are collectively termed total dissolved solids (TDS), and are composed mainly of sodium (Na⁺) and chloride (Cl⁻) (90 and 98%), and potassium (K⁺) and magnesium (Mg⁺²) (5 and 4%) (White 2002, p. 451). A small amount of calcium (Ca⁺²) and sulfate (SO₄⁻²) ions make up the remainder of the TDS. Potassium and magnesium are the economic products extracted from the brine by the potash company. The next four figures (Figures 4-7) show the rain-winter-transient pond and spring-summer evaporation effects on the salt crust without human-made impacts.

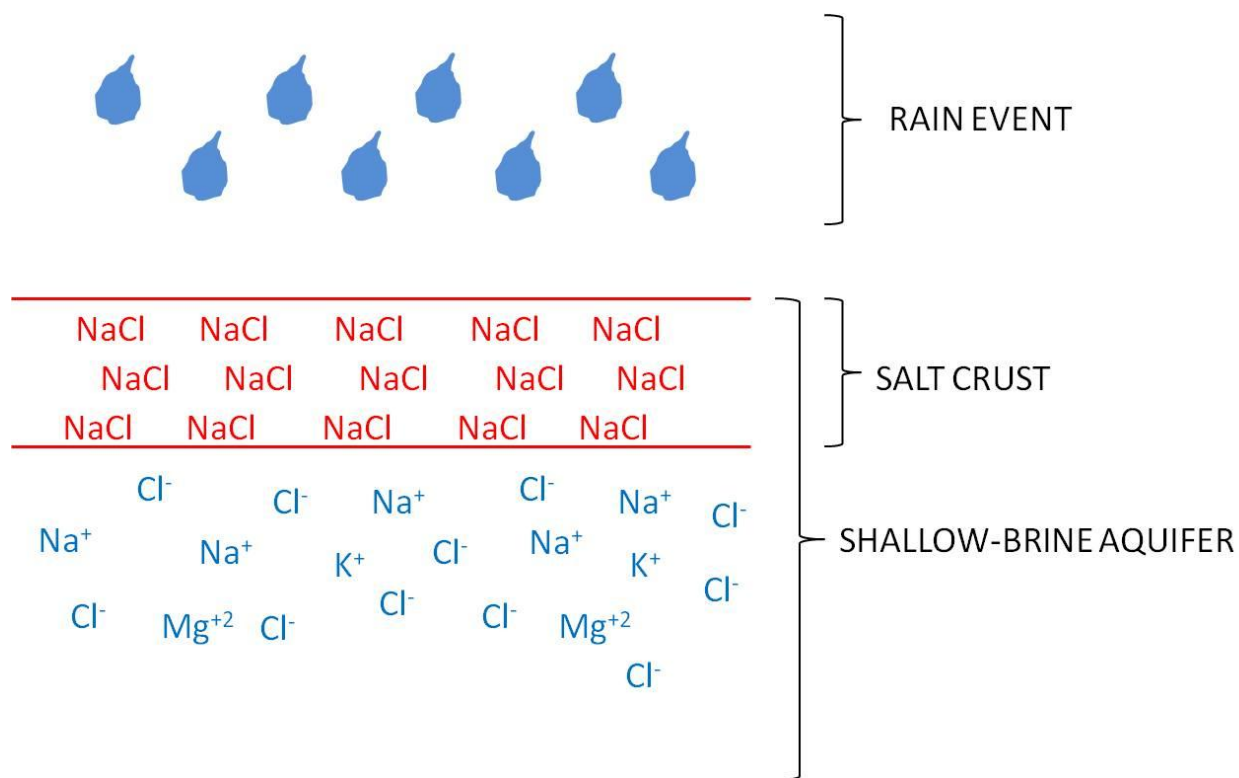


Figure 4. - Initial rain event falling upon the surface of the salt crust. Annual meteoric precipitation (expressed as rain) averages about 5 inches per year (White 2004, p. 247, Table 3). The action of rain water ponding on the surface of the salt crust results in nearly instantaneous dissolution of a thin layer of surface halite.

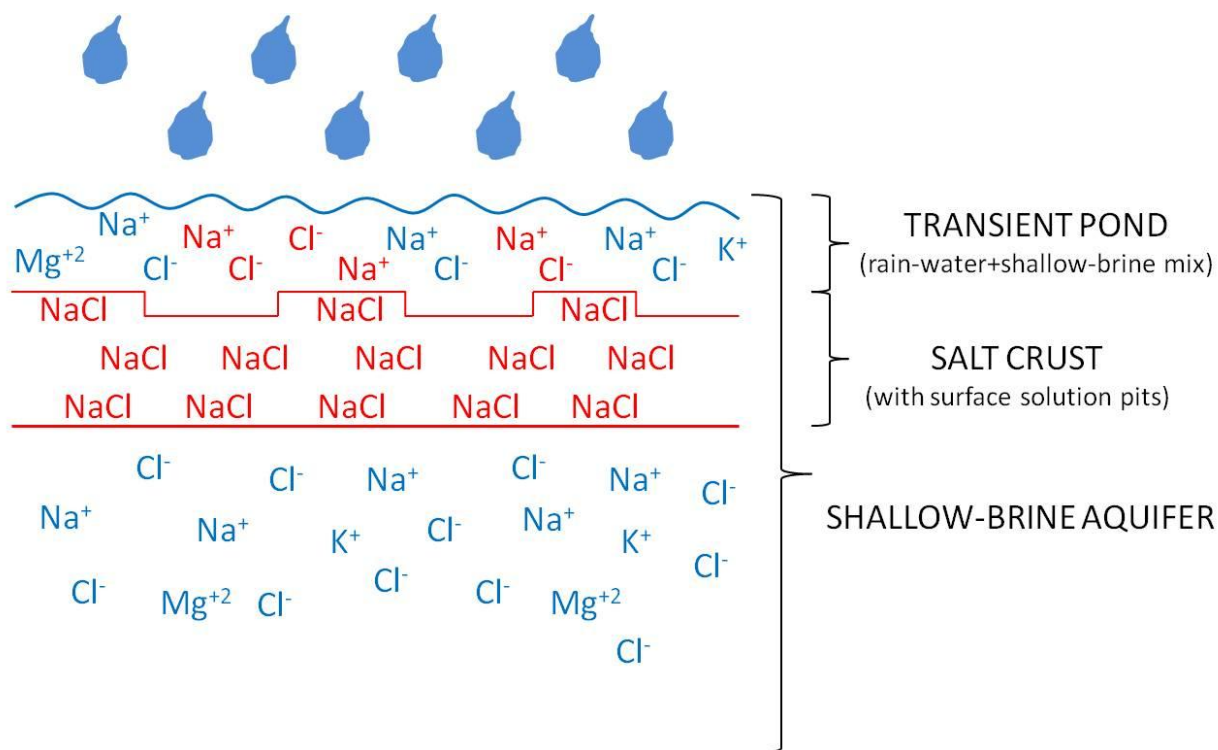


Figure 5. - Because effects of evaporation usually diminish during the period November through April, the upwelling shallow-brine aquifer (blue-colored ions) forms a transient pond, which combines with fresh-water rain events occurring during the same period. The overall effect is to dissolve additional thin surface layers of salt crust (shown as solution pits) into the briny transient winter pond (red-colored ions). Because the transient winter pond is hydrologically connected with the shallow-brine aquifer, mixing of the transient-pond with the shallow-aquifer brines occurs (see Figure 6).

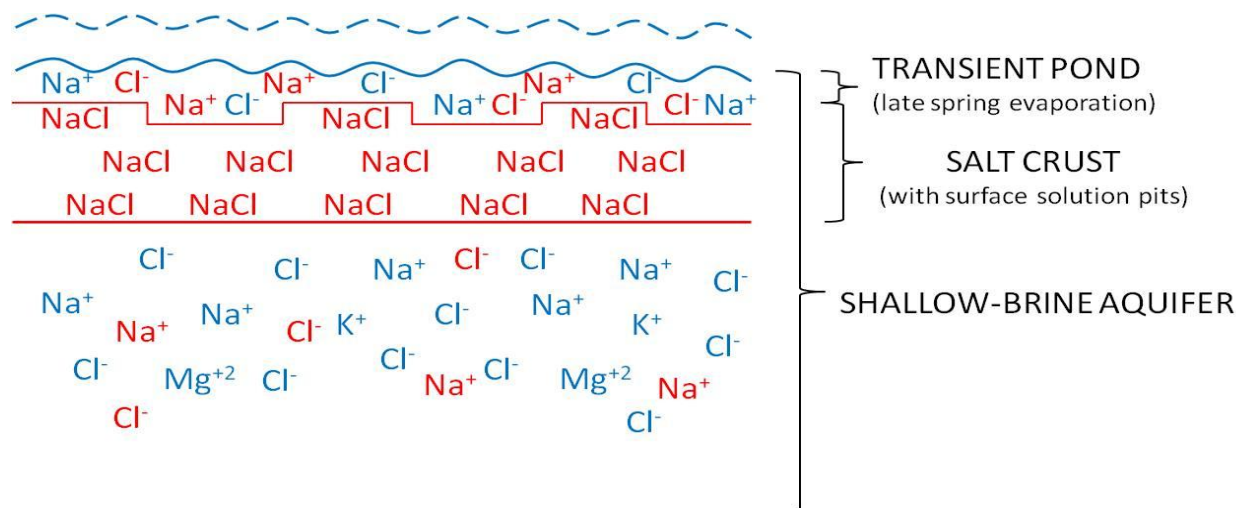


Figure 6. - As late spring advances into summer, the transient pond continues to evaporate as the seasonal temperature warms up. As the volume of the transient pond decreases from evaporation caused by increasing seasonal temperature, the mix of sodium and chloride ions in the pond becomes so concentrated that the brine is eventually oversaturated with dissolved ions (i.e., blue ions from the shallow-brine aquifer and red ions from dissolution of surface halite). Consequently, the sodium and chloride ions precipitate back onto the salt-crust surface as the mineral halite. As the residual transient pond approaches being oversaturated with sodium and chloride ions, its density increases; because it is hydrologically connected with the shallow-brine aquifer, the more dense brine sinks and mixes with the less dense shallow-brine aquifer (thus, the combination of blue and red ions shown in the shallow-brine aquifer).

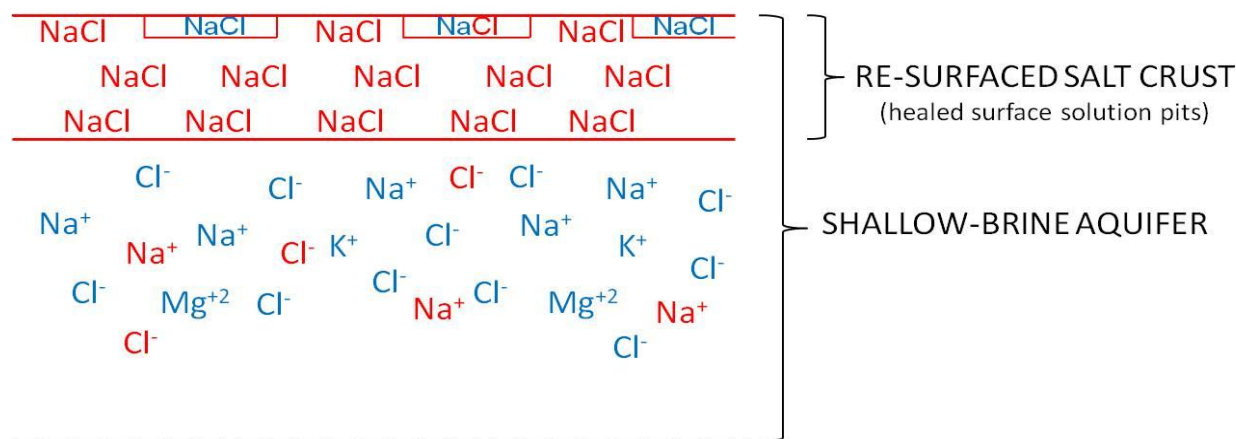


Figure 7. - The end result of the previously-described cycle is threefold: 1) because the Bonneville Salt Flats and surrounding playa are contained within an enclosed basin that has no external drainage, all aqueous and solid-phase products previously described remain within the basin (no exterior transport); 2) the dissolved sodium chloride from the salt-crust halite resides both as re-precipitated halite (re-surfacing & healed dissolution pits) and as part of the shallow-brine aquifer; 3) although individual ions may be transported from solid to aqueous phases (and vice-versa), the ion-mass balance is preserved within this enclosed system.

Potential for Salt Laydown Project to Help Maintain Ion Mass Balance (Figures 8 – 15)

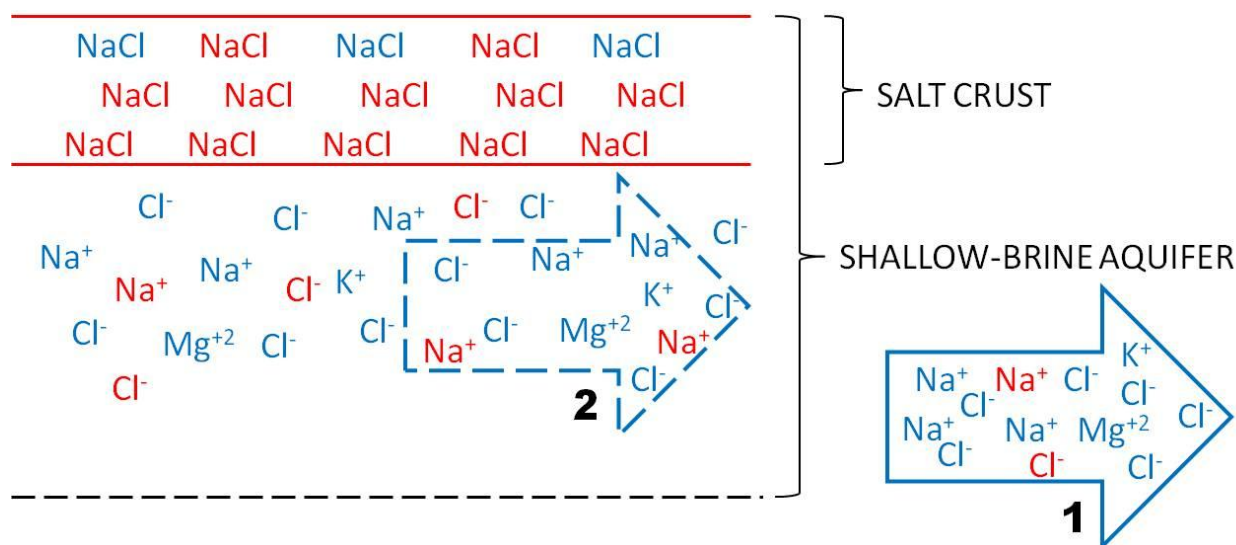


Figure 8. - This figure shows the salt crust and shallow-brine aquifer in the beginning stages of brine withdrawal for mineral production. Note that prior to brine withdrawal, the salt crust shows results of the previously-described natural dissolution and re-precipitation (blue NaCl) cycle, and the mix of salt-crust generated ions (red-colored ions) with those of the shallow-brine aquifer (blue-colored ions). The solid-blue arrow (#1) containing shallow-brine aquifer ions represents brine withdrawal for potash processing. Note that the brine is dominated by sodium and chloride ions, which are a mix of ions from dissolution of the salt crust and from the shallow-brine aquifer, along with minor amounts of potassium and magnesium. The dashed-line blue arrow (#2) represents the volume and ion mass withdrawn from the shallow-brine aquifer.

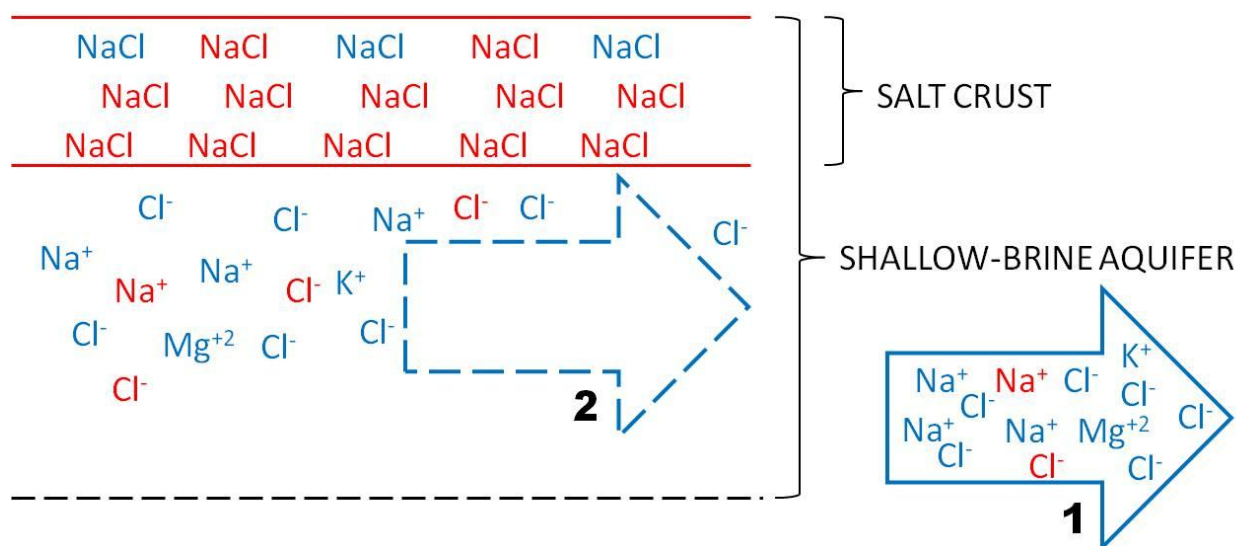


Figure 9. - The empty dashed-line blue arrow (#2) represents the volume of shallow-brine aquifer and resulting ion mass that needs to be replaced to maintain a balanced system.

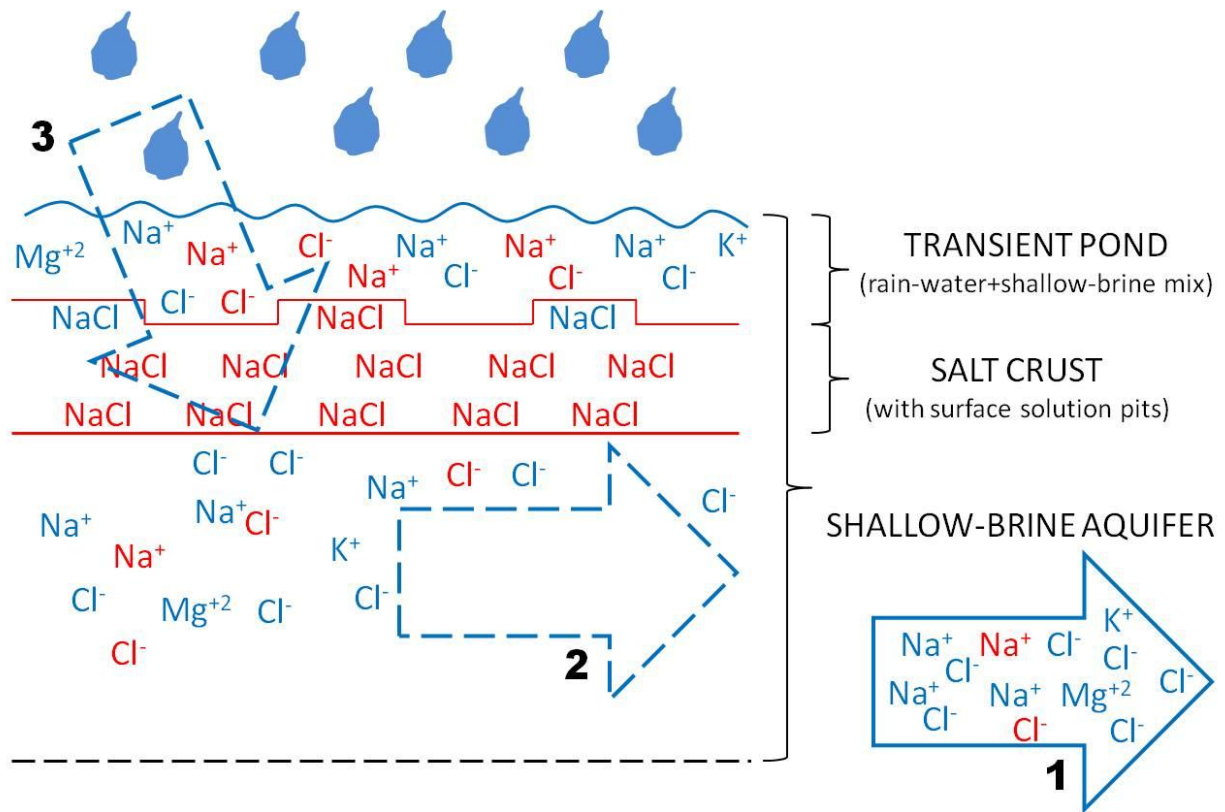


Figure 10. - To replace that which has been withdrawn and still maintain balance within the system, several events must occur: 1) recharge of the system is mainly from rain fall directly onto the salt crust and surrounding mudflat playa; 2) rain fall during November through April mixes with the transient winter pond and results in dissolution of thin layers of surface halite; 3) as the winter transient pond and rain-water mix evaporates, it mixes with the hydrologically-connected shallow-brine aquifer (arrow #3), ultimately transporting sodium and chloride ions dissolved from the salt crust into the shallow brine aquifer filling the gap in arrow #2 (see Figure 11).

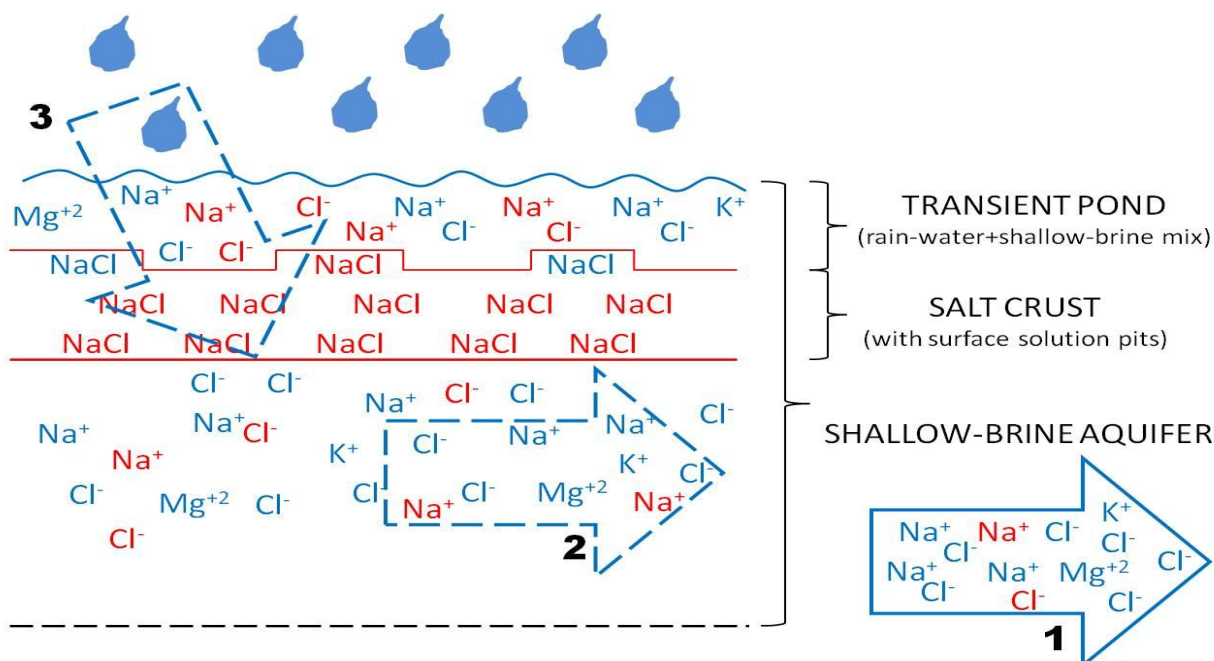


Figure 11. - Ions from dissolution of the salt crust are mixed with the transient pond and ultimately transported into the connected shallow brine aquifer (arrow #3) to replace the ions in the shallow brine aquifer (arrow #2) that were transported with the withdrawn brine (arrow #1).

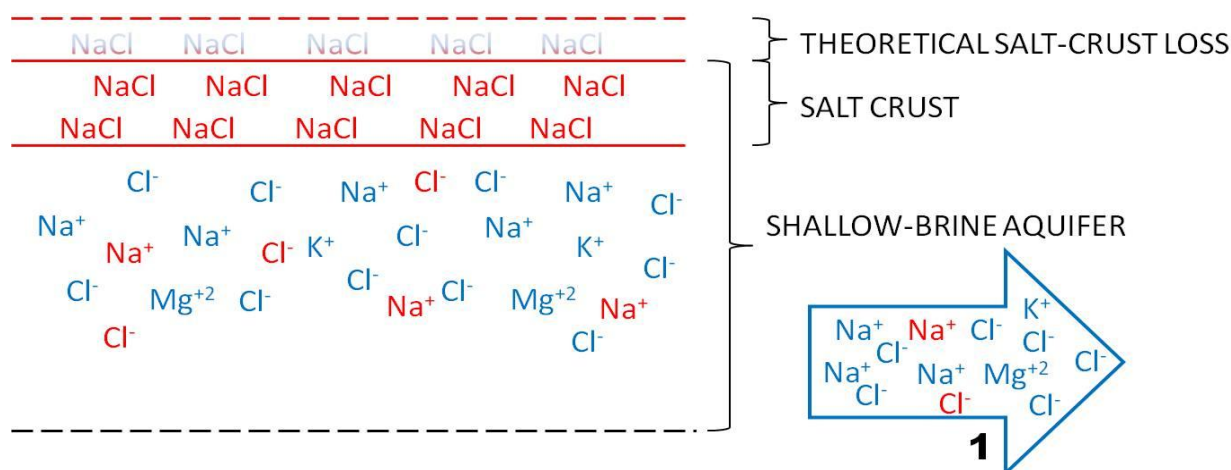


Figure 12. - Recharge of additional ions to the shallow-brine aquifer in the vicinity of the salt crust and surrounding playa is likely supplied by brine transport from the periphery of the 975 square mile area that contains the shallow brine aquifer (see Figure 1). However, the rate of this ion transport is believed to be quite slow. Consequently, it may not be able to keep up with commercial brine withdrawal over time. Therefore, if brine withdrawal were to continue without sufficient ion recharge, it is possible that to maintain ion balance within the shallow-brine aquifer associated with the salt crust, some salt crust could be consumed (depicted by “theoretical salt-crust loss”). While this is theoretically possible, we currently have no way of predicting how many decades this would take and what it would actually look like. So far, no salt crust volume or thickness reduction has been observed either from short-term (6 years – 1997-2003) or long-term (15 years - 1988-2003) brine withdrawal (White and Terrazas 2006).

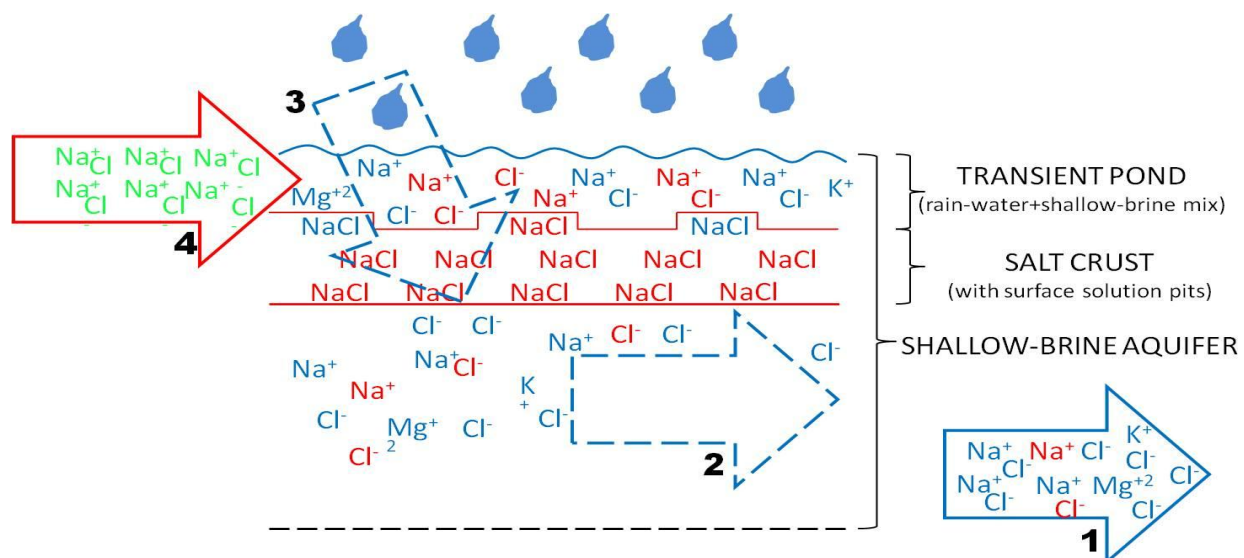


Figure 13. - Red arrow (#4) illustrates human-made addition of sodium and chloride ions (green ions) to the salt-crust and shallow-brine aquifer system in the form of the Salt-Laydown Project (a cooperative experiment between U.S. Bureau of Land Management and the potash-mining company). As was illustrated in Figures 10-11, without sufficient ion recharge to the system, dissolution of salt crust provides ions to replace those lost from brine withdrawal (arrows #1-3). The Salt-Laydown Project is attempting to augment this ion recharge.

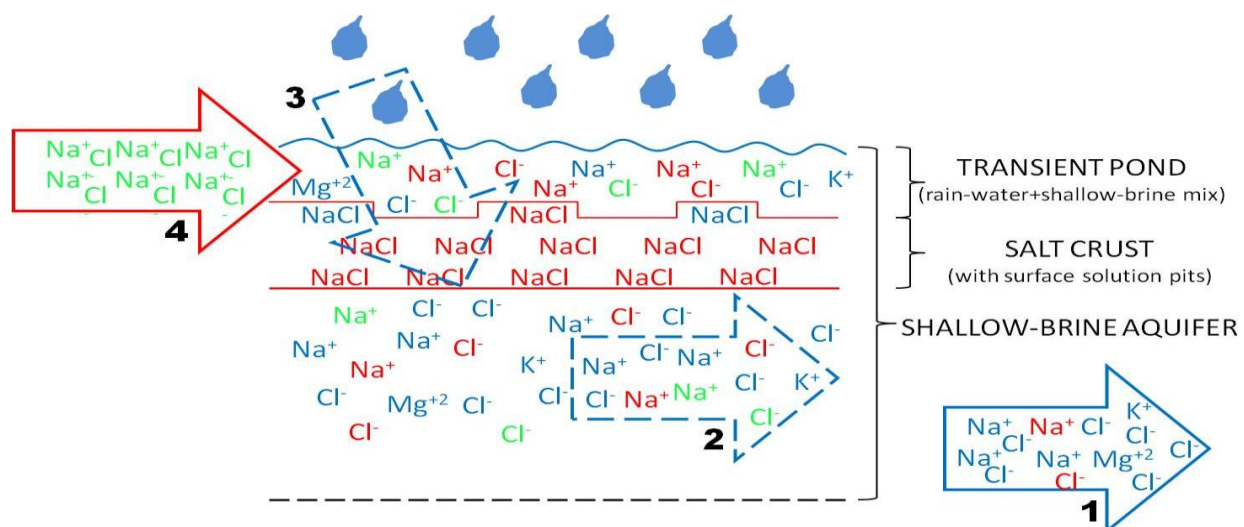


Figure 14. - The Salt-Laydown Project (arrow #4) adds brine that is nearly saturated with sodium chloride ions (green ions) to the transient winter pond. Consequently, the transient winter pond becomes a mix of shallow-brine aquifer ions (blue), dissolved salt-crust ions (red), and Salt-Laydown Project ions (green). Ions from the transient pond are ultimately transported into the connected shallow brine aquifer (arrow #3) to replace the ions in the shallow brine aquifer (arrow #2) that were transported with the withdrawn brine (arrow #1).

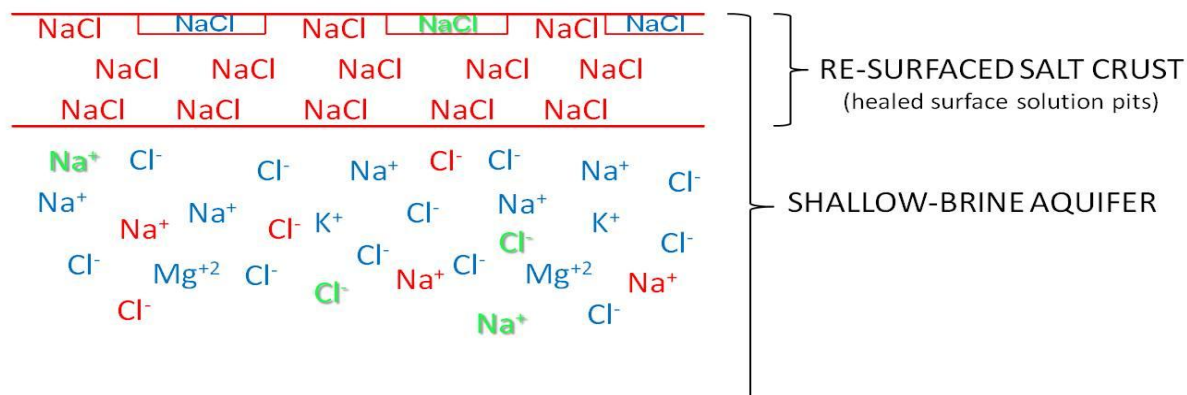
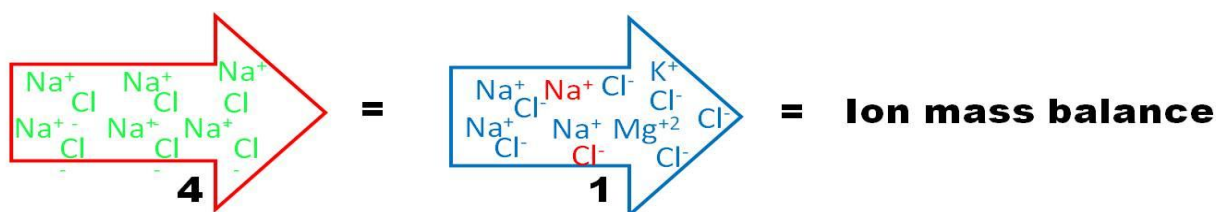


Figure 15. - The ultimate objective of the Salt-Laydown Project (arrow #4) is to replace those ions from the shallow-brine aquifer that are removed during the potash-mining process (arrow #1). This is what we mean by maintaining the ion-mass balance of the system. Note replacement of dissolved salt crust with ion contribution from both shallow-aquifer (blue) and Salt-Laydown brine (green), and contribution of Laydown ions (green) to the shallow –aquifer brine.

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